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ARCHEOLOGY vs. GROUNDWATER

by

John E. Ehrenhard
Midwest Archeological Center
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The basis of this paper was the archeological investigations conducted at Fort Moultrie (FOMO) this past summer by the Southeast Archeological Center of the National Park Service.

The project, initiated in 1973 under N. P. S. contract with the South Carolina Institute of Anthropology and Archeology, was necessitated by the Fort Sumter National Monument Master Plan; a part of which called for the completion of archeological research needed to restore and interpret the resources of Fort Moultrie. Archeological investigations were also to be conducted where proposed constructions might adversely affect archeological or historical values. These topics have been discussed in the preceeding paper by Dick Hsu.

FOMO is situated on an island just outside the north bank of the Charleston Harbor. Its low profile, never rising higher than 10' above sea level provided the archeologists with a serious hydrological problem as ground H_2O, which fluctuated with the tides, was reached in our excavations anywhere from 2-4' below the present day surface.

The never ending infiltration of H_2O into the excavations, malfunctioning pumps, clogged well points and lines became such a headache that the subject of ground H_2O, the nature of soil bodies, and the mechanics of dewatering became a topic of interest. I would like to take this time to make some general comments with respect to these subjects based on our admittedly limited experience and belated revelations.

Nature of Soil Body

For simplicity, it will be assumed that all soils can be divided into two classes which will be referred to respectively as sand and clay. In general, sands are composed of macroscopic particles that are "rounded" or angular in shape. They drain readily, do not swell, possess insignificant capillary potential, and when dry exhibit no shrinkage. Clays, on the other hand, are composed of microscopic particles of platelike shape. They are highly impervious, exhibit considerable swelling, possess a high capillary potential and demostrate considerable volume reduction upon drying.

In problems dealing with ground H_2O the "soil body" is considered to be a continuous medium of many interconnected openings which serve as the fluid carrier. That portion of a soil not occupied by solid matter may be occupied by ground H_2O. These spaces are known as voids. The nature of the pore system within the soil can best be visualized by inference from the impermeable boundaries composing the pore skeleton. They are fundamentally important as they act as ground H_2O conducts. Typically they are characterized by their size, shape, irregularities and distribution.

Let us assume for the purposes of this discussion that the soil particles are all of uniform spherical shape. The porosity of a soil is a measure of the contained voids and may be expressed as the percentage of void space to the total volume of the mass. Calling the total volume (V) and the "volume of voids" (V_1), we have for the porosity: $P = \frac{V_1}{V}$, and for the void ratio: $V_r = \frac{V_1}{V - V_1}$.

For a cubical array of uniform spheres porosity can be expressed as: $P = 1 - \frac{\pi}{6} = 0.476$. For a rhombohedral packing, which represents the most compact assemblage of uniform spheres, the porosity is: $P = \frac{1-\sqrt{2}}{6}\pi = 0.26$. Figure (1) shows the pore volume available for the flow through the cubic and rhombohedral array respectively. It should be noted that even in the ideal porous medium the pore space is not regular but consists of cavernous cells interconnected by narrower channels. Natural soils contain particles that can deviate considerably from the spherical shape and are far from uniform in size. The true nature of the pore channels defies rational description.

The subsurface occurrence* of ground water may be divided into zones of <u>saturation</u> and <u>aeration</u>. In the zone of saturation all voids are filled with water under hydrostatic pressure. The zone of aeration consists of voids occupied partially by water and partially by air. Water occurring in the zone of saturation is commonly referred to simply as ground water. This general zone may be further subdivided into the (1) soil water zone, (2) intermediate zone, and (3) the capillary zone; thickness of zones vary with soil types and vegetation.

* HAROLD: I AM SORRY THAT GRAPHICS OF THE SUBSURFACE OCCURRENCE ARE ON 35 MM SLIDES. JERRY LIVINGSTON HAS DRAWINGS WHICH I WILL HAVE HIM SEND TO YOU.

JOHN

Soil Water Zone: Water in soil H_2O zone exists at less than saturation except temporarily when excessive water reaches the ground surface as from rainfall or irrigation.

Intermediate Zone: The intermediate zone extends from the lower edge of the Soil Water Zone to the upper limit of the Capillary Zone. It may vary in thickness from zero, when the bounding zones merge with a high water table approaching the ground surface to several hundred feet, under deep water table conditions. The zone serves primarily as a region connecting the ground surface to that near the water table through which water moving vertically downward must pass.

Capillary Zone: The capillary zone extends from the water table up to the limit of capillary rise of water.

Saturated Zone: Ground water fills all of the voids in the saturated zone.

The principle of operation in "well pointing" is to drive a pipe or pipes into the ground ahead of excavation so that the water may be drawn from the subsoil by pumping. Usually water under pressure is used to jet a hole large enough for the point to enter the ground. Choking of the screen can be overcome by jetting a hole larger than the point so that the space around it can be filled with coarse sand or fine gravel which will form a screen additional to that provided by the well-point.
(Fig 2)

When the points have been sunk "swing arms" are connected to the suction header and stop valves, fitted between the header and swing arms, allow for the isolation of any well-point. Connections from the well-point must always rise to the header which should in turn rise to the pump. This will eliminate the possibility of vapor locks forming.

(Fig 3)

Well points are used in either a "progressive" or "ring" layout. The progressive layout is used for excavating trenches, the ring system for excavating a set area. In the progressive layout the suction header is placed alongside the line of the proposed trench. Depending upon the strata and quantity of water to be handled, either a single row of well-points or one on each side of the trench are required. If the trench is being excavated by hand, the points may be located close to the trench sides, but if heavy equipment is used suction heads should be outside the tracks of the machine. Points can be spaced at standard intervals or multiples of standard intervals according to the nature of the ground and the quantity of H_2O. In fine running sand wide spacing will usually suffice, but in loose gravel or coarse sand where large volumes of H_2O are encountered close spacing may be necessary.

Typical pumping equipment consists of a self-priming single stage centrifugal pump. This type of pump will lift a liquid provided the pipe between the supply and the pump housing enclosing the impeller is completely filled with water before the machine is started. Pumping will continue so long as no air accumulates around the impeller.

A certain amount of pressure is required to get water to flow into a pump before additional pressure or velocity can be added. For our purposes this "head" is expressed as energy/pounds due to pressure and is known as the "Net Positive Suction Head" or (NPSH). A pump must be installed so that the head available at the intake is equal to or greater than the rated NPSH of the pump. If the available head is less than the required NPSH, the pressure in the well point reduces to the vapor pressure of water and the pump will "cavitate". Cavitation is the formation of a vacuous space around the impeller which is normally occupied by water. This subsequently reduces the pumping capacity.

When a well point is pumped, water is removed from around the point and the water table is lowered. The draw down at a given point is the distance the water level is lowered. A draw down curve shows the variation of draw down with the distance from the well (fig.4). In three dimensions, the draw down curve describes a conical slope known as the cone of depression. The outer limits of the cone defines the area of influence of the well.

For a given well, the draw down can be determined at any point if the well discharges are known, or vice versa. The draw down at any point in the area of influence is equal to the sum of the draw downs caused by each well individually. Thus:

$$D_T = D_A + D_B + D_C \ldots + D_N$$

Where D_T is the total draw down at a given point and D_A, D_B, D_C, D_N, are the draw down at the point caused by the discharge of wells A, B, C, N respectively. The summation of discharge may be illustrated as shown (fig.5); the individual and composite draw-down curves are given for Q_1, Q_2, Q_3.

The purpose of well screens and gravel packs are to maintain open access within the water bearing stratum while ensuring that it operates freely once installed. A screen, and many times a gravel pack, are an absolute necessity if the well draws on fine unconsolidated sands. The screen and pack should first prevent the collapse of the well due to the abstraction of large quantities of sand, and secondly, damage to the pump due to sand particles in the water.

The use of correctly designed equipment is important to the overall efficiency of the dewatering system. Well screen designs should incorporate the following features:

1. prevent movement of sand into the well
2. have effective nonclogging openings; slot size should match gravel pack medium or that of the surrounding area
3. maximum open area of screen
4. adequate strength to prevent its collapse
5. have a low inlet resistance
6. screen should be corrosion resistant

Gravel packs should include the following design features:

1. sand free after development
2. give lowest possible resistance to permeation
3. offer low entrance velocities

The gravel pack should ensure that the completed well operates free of sand; thus the particle size of the pack depends upon the particle size of its surroundings.

There are several basic requirements for a gravel pack: For formations of sand the aquifer must be stabilized. It is not usually practical to have very small slot sizes, and so an artificial gravel pack should be selected which forms the correct size of pore opening, and stabilizes the sand in formation. The use of a pack in a sand formation enables the screen opening to be considerably larger than if the screen were placed in the formation by itself. The pack adjoining the screen consists of larger sized particles than the surrounding formation, and hence larger voids are formed at and close to the screen allowing water entry nearly free from head loss.

The grain size of a gravel pack should be chosen so that it ensures that the completed well operates sand free. Standard sieve analyses should be used for all determinations of aquifer size for the design of gravel packs. The gravel pack standard grain size is equal to the aquifer standard grain size X screening factor.

G.P.S.G.S. = A.S.G.S. X Screening Factor

Charts for determining the standard grain size of any type of aquifer are commercially available.

The well screen should not retain all the surrounding aquifer of gravel pack contents, but should be designed to allow the fine and medium size particles to wash out during the development of the well. However, screens still tend to become blocked and restrict the open screen area. Blockage of the openings will cause higher velocities of the H_2O locally which will carry larger particles from the surrounding formation, and lead to further blockage. A uniform distribution of inlet openings will, if spaced as close as possible, provide uniform development over the length of the screen, and so avoid areas of under-development and high velocities.

It is suggested that an open area $>$ 25% gives little increase in efficiency; however, the performance decreases considerably when the open area $<$ 15%. To a point, the higher the percentage of open area available, the more area there is to be blocked before head loss becomes significant, and therefore an additional open area should result in an increase in efficiency over a longer period of time.

The screen length and diameter can be chosen from the slot size and total opening required. Allowance should be made for 50% of the open area becoming blocked. The screen length is a function of the hydrogeology, while diameter depends primarily on choice, method used to drill well, or a combination of both.

Determination of screen slot size depends on the critical particle size of the aquifer or gravel pack to be retained. A standard sieve analysis of the aquifer or pack determines this size (commercially available).

Commercial well screens slot design:

1. slotted rings
2. wedge-shaped bars or rings
3. bridge slots
4. louvre slot

In the design of simple slotted screens it was found that circular perforations were not satisfactory, and oblong slots were developed. These have open areas as high as 40%; however, the slot was completely punched out and there was considerable loss of strength. The slots may be vertical or horizontal, but it is suggested that vertical slots may not stabilize fine particles. Horizontal slots stabilize these particles, but they tend to "bridge over" the slot. These screens tend to have a high degree of blockage.

A temporary form of screen is the mesh type, in which a wire screen mesh is placed around a well perforated tube. High corrosion and clogging are the disadvantages that occur with this type of screen.

Wedge-shaped bars or rings can be arranged to give a continuous opening in the form of an 'inverted V', with the narrow opening on the aquifer side, either in the vertical or horizontal plane. Horizontal slots are usually formed on a continuous wire-wound process. Advantages claimed are that a large open area is given, slot width can be varied over a large range, and that the wedge-shaped bars or rings give strength. Clogging is said to be small; however, the effective open cross-sectional area may be limited by the transverse or longitudinal bracing.

The bridge slot screen is an adaptation of the simple slot screen, only here the perforation is not completely pressed out, but is allowed to form a bridge over the opening. This produces a higher strength than simple slot designs, and gives up to 30% open area. A limited series of slot sizes can be provided and good gravel deflectors are formed.

If the hole is pushed out of the screen, so that a small "roof" is left projecting over the hole, then the louver perforation is formed. Claims are made that:

1. gives added strength
2. material is prevented by the roof from running down into the well
3. as there are no parallel surfaces, the degree of clogging is small

Screen Material

Well screens are readily supplied in a number of materials:

commercial steel

steel coated with chlorinated rubber

galvanized steel

plastic coated steel

plastic

copper

stainless steel

aluminum

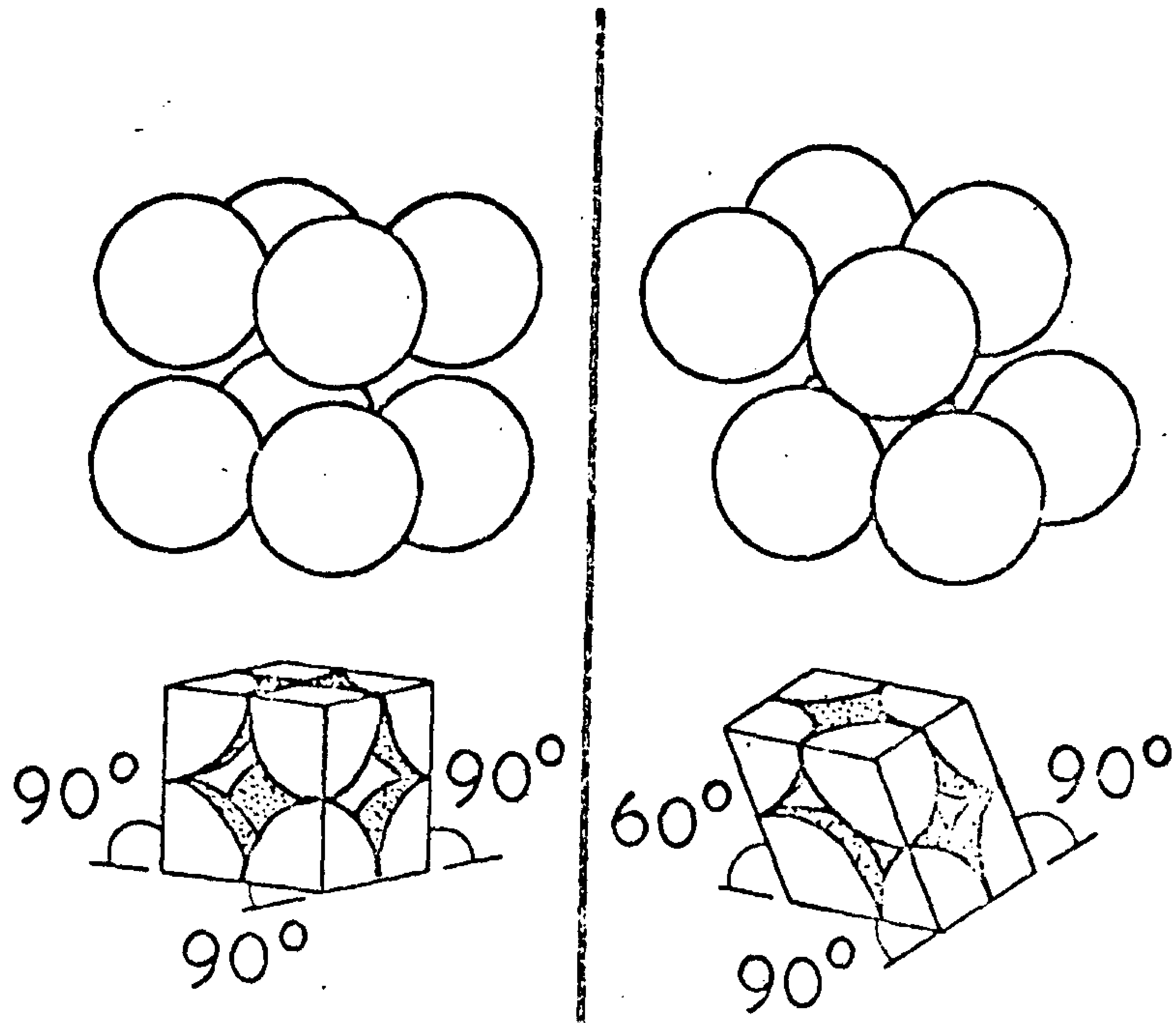
fiber glass

In conclusion, it must be remembered that each site necessitating dewatering will involve its own special problems involving soils, porosity, amount of H_2O, etc. What works at one site may or may not work elsewhere.

An understanding of possible hydrological problems with possible solutions thought out in advance of field work can in many instances save valuable time and expense.

I hope that the few points mentioned here may be of some help to those of you who may be dealing with problems of dewatering in future excavations.

FIG. I



Spherical Packing

Rhombohedral Packing

FIG. 2

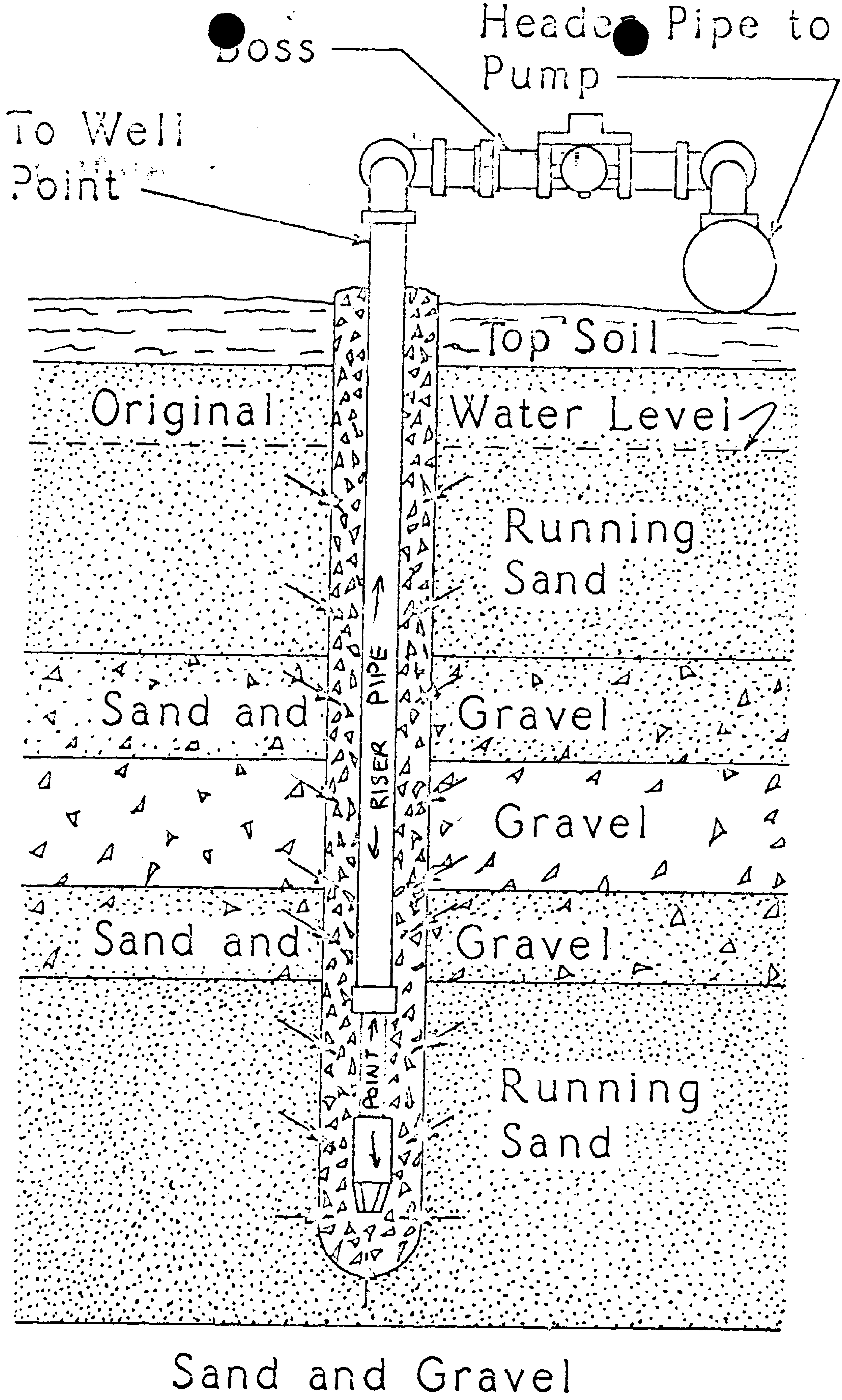
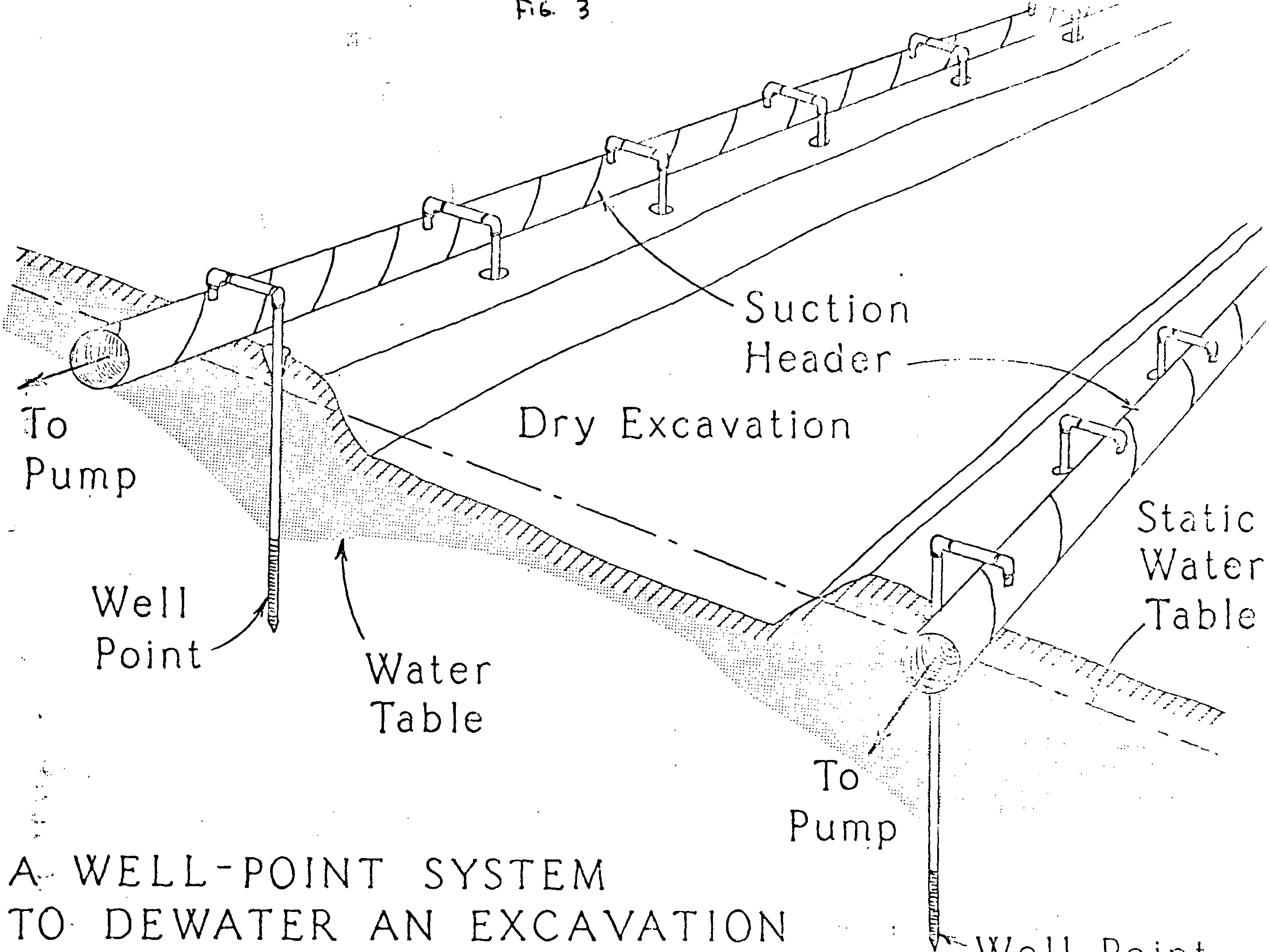

Boss
Header Pipe to Pump
To Well Point
Top Soil
Original Water Level
Running Sand
Sand and Gravel
Gravel
Sand and Gravel
RISER PIPE
POINT
Running Sand
Sand and Gravel

FIG. 3



A WELL-POINT SYSTEM
TO DEWATER AN EXCAVATION
SITE

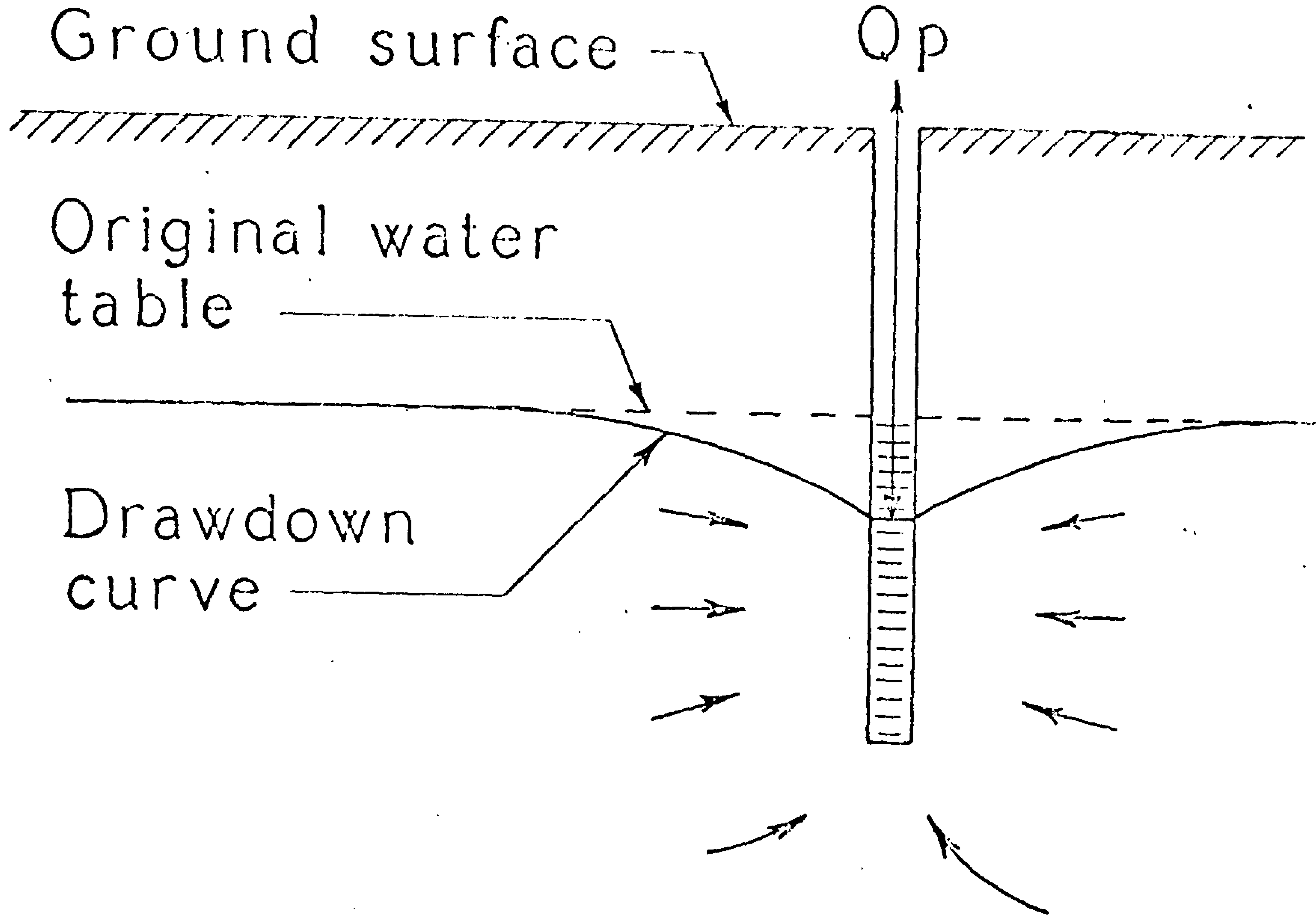


FIG. 4

FIG. 5

Individual and composite drawdown curves for three wells in a line.